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DIVISION OF CHEMISTRY
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UTILIZATION OF VITAMIN A BY DAIRY COWS

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
T. O. WALTON, President

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The vitamin A potency of butter from the 9 Jersey cows studied decreased from 43 and 62 Sherman-Munsell units per gram at the beginning of the experiment to 4 units per gram for cows receiving 7,000 units per day, to 12 units for cows receiving 170,000 units per day, and to 10 units for cows receiving 340,000 units per day at the end of seventeen weeks. The carotene decreased from 16.7, 9.7, and 9.8 parts per million in the beginning to 0.4, 3.9, and 3.6 parts per million respectively for the three levels of vitamin A consumption.

The apparent recovery of the vitamin A potency in the butter varied from 213 to 2.4 per cent of that in the feed. The apparent percentage recovered was greatest at the beginning of the experiment and greatest also for the cows receiving the least amount of vitamin A in the feed. The high percentage of vitamin A apparently recovered was due to the fact that some of it came from that stored in the body of the cow.

If correction is made for the vitamin A potency stored by the cows, the average utilization was 2.38 to 2.67% for the five periods.

The vitamin A potency of the butterfat from some of the cows was higher than that of others fed on the same feed for the same period of time. Some cows appear to have a greater power than others to secrete vitamin A and carotene into the butter.

Sorghum preserved with mineral acids (A. I. V. silage) was low in carotene and had only a slight effect upon the carotene and vitamin A in the butter when fed to cows previously depleted.

When two cows were depleted by feed low in vitamin A and then placed upon pasture, the vitamin A potency of the butter increased from 12 units per gram to 40 or 50 units per gram within three days.

When other depleted cows were placed upon pasture, there was likewise a rapid increase in the vitamin A potency of the butter. The carotene in the butterfat reached the maximum of 13.96 parts per million with one cow in 28 days and a maximum of 19.06 with the other cow in 14 days followed by a decrease with both cows. There was a rapid increase in spectro-vitamin A, which reached a maximum in fourteen days. One cow apparently had a greater capacity to secrete vitamin A and carotene in the butterfat than the other.

The vitamin A potency of the butter of the cows on pasture was high, a maximum of 72 Sherman-Munsell units with one cow and 101 units for the other as calculated from the carotene and spectro-vitamin A.

The vitamin A potency of the butter is closely related to the vitamin A potency of the feed and the period of time the cow has been receiving it. It is calculated from this work and that of others that from 750,000 to 1,400,000 Sherman-Munsell units are required per cow per day to produce butterfat containing from 65 to 95 Sherman-Munsell units per gram, the amount found in very good butter.

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UTILIZATION OF VITAMIN A BY DAIRY COWS

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It is now known that the vitamin A potency of butter is closely related to the vitamin potency of the diet of the cow. It has recently been shown by us (5) that cows which had access to pasture before but not during lactation produced butter high in vitamin A at first, but that the vitamin A potency of the butterfat decreased during the period of lactation. The vitamin A potency of the butter depended not only upon the vitamin A potency of the feed but upon the previous feed of the cow before the lactation started or during lactation and the length of time the cow had been receiving the feed at the time the sample of butter was taken. The decrease in vitamin A potency was greater when the feed was low in vitamin A than it was when the feed was high in vitamin A, but a decrease occurred even with feed high in vitamin A. Cows which were in the later periods of lactation and were producing butter very low in vitamin A potency, after being placed on pasture produced butterfat high in vitamin A potency (5). The decrease therefore was due to insufficient vitamin A potency in the feed and not to the stage of lactation. We have also shown (15) that butterfat naturally of deep yellow color was likely to contain more vitamin A potency than light-colored butter. Other workers (11) have also correlated the yellow color or carotene of butterfat with its vitamin A content. Additional references may be found in previous publications (15).

Cows in general secure their vitamin A potency from the carotene in grasses and fodders and from cryptoxanthine and carotene in yellow corn. Cows receive vitamin A as such only if they are fed cod liver oil, or a concentrate of fish liver oil or certain other fish oils. The carotene and cryptoxanthine in the feed is partly converted into vitamin A since both vitamin A and carotene may be found in the blood, and liver, and in the butterfat of animals receiving only carotene as a source of vitamin A. Baumann et al (2) calculated that on a low carotene ration 1.6 per cent of the vitamin A potency and 1.1 per cent of the carotene ingested was secreted into the milk, and that on a high carotene ration only 1.3% of the vitamin A potency and 0.4 per cent of the carotene fed was secreted. Russell (13) reported that 2.5 to 3.4% of the vitamin A value of dried alfalfa and corn silage usually appeared in the milk on a daily intake of 1,213,500 to 946,700 U. S. P. 1934 units per cow. Peterson et al (12) stated that only about 2% of the carotene appeared in the butterfat when the cow was fed high amounts, 298 to 561 mg. of carotene per day, of A. I. V. alfalfa silage. These results indicate the apparent utilization at definite periods and do not allow for the vitamin A stored in the body of the animal.

It has been shown in Texas Bulletin 495 (5) that 116,000 Sherman-Munsell units of vitamin A potency per day in about 7 pounds of yellow corn and 6 pounds of alfalfa leaf meal was not sufficient to maintain the vitamin A potency of the butterfat. In this work, on an average, one unit of vitamin A potency in the butter required approximately 11 units in the feed over maintenance requirements. As the experiment we conducted was made with only three cows and there may have been differences in the quantities of vitamin A potency stored by the cows, a considerable latitude for error must be allowed on account of the necessary corrections for storage and maintenance requirements. It was considered desirable to make a similar experiment with a larger number of cows at higher levels of vitamin A potency. Experiments were also made to ascertain the time required for carotene fed to the cow to appear in the butterfat and be converted into vitamin A.

Method of Procedure

In the experiments reported here on the utilization of vitamin A potency of feeds, nine Jersey cows, divided into three equal groups, were used. The cows had been fed alike upon the usual ration, including pasturage, given cows before calving. Five days after the cows had calved, they were placed upon the experimental ration. All the cows received daily about 20 pounds of cottonseed hulls and 15 pounds of beet pulp. Block salt and tap water were also provided. The grain mixture fed the cows consisted of 60 per cent yellow corn, 27 per cent cottonseed meal, 10 per cent wheat bran, 2 per cent pulverized oyster shell, and 1 per cent salt, made available at the rate of approximately 2½ pounds for each pound of milk per cow daily. One group of three cows received vitamin A potency in yellow corn alone. The second group of three cows received three pounds of heat-dried alfalfa leaf meal in addition to the yellow corn, and a third group of three cows received six pounds of alfalfa leaf meal in addition to the yellow corn. The vitamin A potency was provided by cryptoxanthine and carotene in the yellow corn and the carotene in the alfalfa leaf meal. The first sample of butter was collected at the beginning of the experiment five days after calving, the second at the end of seven days, and the other samples at the ends of periods of twenty-eight days. The dates of calving and the dates of collecting samples of butter are given in Table 1.

The vitamin A potency of the feed was determined by means of rats by the modified Sherman-Munsell procedure already described in detail (4,14). The details of the estimations are given in Table 2. Since there was a decrease in the vitamin A potency of the feed during storage as shown in Table 2 this decrease was considered to be regular at the rate of 7% a month (5,14). The vitamin A assumed to be present in the feed during the various periods is given in Table 3. The samples of the butter were melted, and the fat was separated and kept in an electric refrigerator. As it was not possible by means of rats to determine the

TABLE 1. Age, dates of calving, and dates samples of butter were collected

Cow number	192	356	370	65	363	376	74	301	364
Age of cow, in years and months	8-10	4-0	3-6	5-4	3-8	3-2	3-6	8-2	3-8
Date of calving, 1934	8/27	8/8	9/24	7/30	7/24	9/3	9/13	9/9	7/17
First sample of butter collected, 1934	9/1	8/13	9/29	8/4	7/29	9/8	9/18	9/14	7/22
Second sample collected, 1934	9/8	8/20	10/6	8/11	8/5	9/15	9/25	9/21	7/29
Third sample collected, 1934	10/6	9/17	11/3	9/8	9/2	10/13	10/23	10/19	8/26
Fourth sample, 1934	11/3	10/15	....	10/6	9/30	11/10	11/20	11/16	9/23
Fifth sample, 1934	12/1	11/12	12/29	11/3	10/28	12/8	12/18	12/14	10/21
Sixth sample, 1934-35	12/29	.....	1/26/35	12/1/34	.....	1/5/35	1/15	1/11	11/18/34

TABLE 2. Details of estimation of vitamin A potency of feeds in Sherman-Munsell units per gram

Laboratory Number	Feed tested	Date sampled	Grams fed per day	Number of rats at beginning	Number of rats at end	Average gain per rat in 8 weeks	Units vitamin A potency per gram
40626	Shelled yellow corn	8/30/34	.15	6	1	—33	....
			.20	6	3	—20	....
			.30	6	3	3	....
			.40	6	3	28	2.6
40627	Heat dried alfalfa leaf meal	8/30/34	.0066	6	2	23	143.
			.01	6	4	44	....
			.0133	6	5	46	....
			.02	6	6	40	....
			.03	6	6	63	....
			.04	6	6	71	....
			.05	6	5	65	....
41110	Shelled yellow corn	11/16/34	.15	6	1	—9	....
			.20	6	2	2	....
			.30	6	2	35	....
			.50	6	6	28	2.1
41111	Heat dried alfalfa leaf meal	11/16/34	.0066	6	0	—	....
			.01	6	2	—4	....
			.0133	6	4	39	85.

TABLE 3. Assumed vitamin A potency of feed by months, in Sherman-Munsell rat units per gram

	Yellow corn	Alfalfa leaf meal
August	3.4	151
September	3.2	141
October	3.0	131
November	2.8	122
December	2.6	114
January	2.4	106
February	2.1	99

vitamin A potency of all the individual samples of butter, the three samples from the three cows on the same feed were combined in one sample for each period and the vitamin A potency in this mixture was estimated by means of rats as previously described (4,14). Details of this estimation are given in Table 4. A summary of the vitamin A potency of the butterfat in Sherman-Munsell units per gram is given in Table 5.

TABLE 4. Details of estimation of vitamin A potency of butterfat

Laboratory Number	Description	Alfalfa fed pounds	Butter-fat fed per day grams	Number of rats at beginning	Number of rats at end	Average gain per rat in 8 wks. grams	Vitamin A units to one gram fat
40925	First samples, beginning of test 5 days after calving....................	3	.02	6	4	22	50
			.033	7	5	49	
40930	" " "	0	.02	6	5	18	43
			.033	6	6	35	
40952	" " "	6	.02	6	3	34	62
			.033	6	5	65	
40954	Second sample, 1 week on feed.................	3	.026	6	5	17	33
			.04	6	4	55	
40955	" " "	6	.026	6	3	32	43
			.04	6	5	64	
40961	" " "	0	.026	6	4	14	33
			.04	6	3	44	
41132	Third sample, 5 weeks on feed.................	6	.033	6	1	22	28
			.05	6	5	50	
41134	" " "		.04	6	0	—	
		3	.05	6	5	23	20
			.07	6	5	53	
41139	" " "		.05	6	2	16	
		0	.07	6	2	25	14
			.1	6	4	39	
41218	Fourth sample, 9 weeks on feed.................	6	.05	6	4	33	23
			.07	6	3	41	
41231	" " "	3	.05	6	4	36	25
			.07	6	4	69	
			.1	6	3	83	
41256	" " "	0	.1	6	5	30	10
			.133	6	4	35	
41265	Fifth sample, 12 weeks on feed.................	3	.07	6	5	23	14
			.1	6	4	29	
			.133	6	3	34	
			.05	6	4	24	20
41282	" " "	6	.07	6	5	35	
			.1	6	4	57	
41299	" " "	0	.1	6	1	11	
			.15	6	3	34	7
			.2	6	4	51	
41362	Sixth sample, 17 weeks on feed.................	3	.07	6	1	26	
			.1	6	3	41	12
			.133	6	4	42	
41384	" " "	0	.1	6	1	—25	
			.15	6	1	9	
			.2	6	1	—5	4
			.3	6	4	58	
41385	" " "	6	.07	6	3	9	
			.1	12	5	23	10
			.13	6	4	34	

Carotene Content of the Butterfat

The quantity of carotene in the butterfat, like that of vitamin A, in addition to the breed of the cow (2), depends upon the quantity of carotene fed and the length of time it has been fed. As shown in Texas Bulletin 513 (15), butter high in vitamin A is likely to be naturally highly colored but all colored butter is not high in vitamin A. Light colored butter is likely to be low in vitamin A. Similar results were secured by Meigs (11).

The carotene in the butterfat was determined by the spectrophotometric method already described (15). Miss Mary Anna Grimes of the Division of Rural Home Research made the spectrophotometric readings. A summary of the results is given in Table 6, together with similar results obtained in previous experiments (5). The periods of time in the earlier work are not exactly the same as in the work here reported.

TABLE 5. Vitamin A potency of butterfat in Sherman-Munsell units per gram

			Experiments in 1935			Experiments in 1933				
Series	End of period	Weeks in experiment	Yellow corn	3 pounds alfalfa daily	6 pounds alfalfa daily	White corn Cow 59	Yellow corn Cow 61	Yellow corn Cow 196	3 lbs. alfalfa Cow 322	6 lbs. alfalfa Cow 329
1	0	0	43	50	62	40	28	25	70	33
2	1	1	33	33	43	25	17	—	—	—
3	2	5	14	20	28	8	12	8	14	20
4	3	9	10	25	23	8	7	8	14	12
5	4	13	7	14	20	17	6	—	—	—
6	5	17	4	12	10	7	5	4	10	11
Approximate units fed per day........			7,000	170,000	340,000	0	17,000	8,400	60,000	116,000

TABLE 5A. Vitamin A potency of butterfat in International units per gram

			Experiments in 1935			Experiments in 1933				
Series	End of period	Weeks in experiment	Yellow corn	3 pounds alfalfa daily	6 pounds alfalfa daily	White corn Cow 59	Yellow corn Cow 61	Yellow corn Cow 196	3 lbs. alfalfa Cow 322	6 lbs. alfalfa Cow 329
1	0	0	52	60	74	48	34	30	84	40
2	1	1	40	40	52	30	20	—	—	—
3	2	5	17	24	34	10	14	10	17	24
4	3	9	12	30	28	10	8	10	17	14
5	4	13	8	17	24	13	7	—	—	—
6	5	17	5	14	12	8	6	5	12	13
Approximate units fed per day........			8,400	204,000	408,000	0	20,400	10,080	72,000	139,200

As in the previous experiments, the amount of carotene in the butter decreased during the period of feeding. The decrease is greater with the yellow corn alone than with the corn and alfalfa meal. The amount of carotene in the butter from the cows receiving the six pounds of alfalfa leaf meal was higher at the end of 9 and 13 weeks than from the cows receiving 3 pounds of alfalfa leaf meal, but it was lower at the end of 13 and 17 weeks. Apparently the larger quantity of carotene in 6 pounds of alfalfa leaf meal had little more effect upon that in the butter than the smaller amount. The butterfat from the cow fed 116,000 units daily in 1933 was higher in carotene than the average of 3 cows receiving about 340,000 units daily in 1935 in 6 pounds of alfalfa meal. This difference may have been due to the individuality of the cow. Baumann et al (2) have shown that Guernsey cows on an average give butter containing more carotene than do Jersey or several other breeds of cows, but since the vitamin A is lower where the carotene is higher, the butterfat does not differ much in vitamin A potency.

TABLE 6. Carotene in butterfat, in parts per million

Weeks on Experiment	Experiments 1935			Experiments 1933				
	Yellow corn	Alfalfa 3 lbs.	Alfalfa 6 lbs.	White corn	Yellow corn	Yellow corn	Alfalfa 3 lbs.	Alfalfa 6 lbs.
0	16.7	9.7	9.8	9.2	10.7	12.8	12.2	13.6
1	7.9	10.5	9.5	5.9	5.6	.....	.....	.....
5	2.0	5.6	5.1	0.7	2.0	3.4	3.6	8.0
9	1.1	4.1	4.5	0.4	1.0	1.4	2.4	7.1
13	0.8	3.5	4.9	0.3	0.6	.....	.....	.....
17	0.4	3.9	3.6	0.2	0.3	1.0	2.4	6.0

Vitamin A Potency of the Butterfat

The data from the estimation, by means of rats, of vitamin A in the butterfat at various intervals are given in Table 5. For comparative purposes, the vitamin A found in similar previous work (Bulletin 495) is also stated. The periods of time are not exactly the same for the different experiments.

The vitamin A potency decreased more during the first week. After the first 4 or 5 weeks, the vitamin A potency had materially decreased. The quantities present in the butterfat from the cows fed yellow corn, in three experiments, were comparatively close at the same periods of feeding. The vitamin A in the butterfat from the cows fed alfalfa meal was higher at the beginning in the 1935 experiment than in the 1933 (5) experiments. This is accounted for by the fact that the cows received much more vitamin A potency in 1935 than in 1933. The alfalfa leaf meal fed in 1934-5 contained 3 times as much vitamin A potency as that fed in 1933. This difference is reflected at first in the vitamin A potency of the butterfat, but it is not apparent at the end of 17 weeks. In spite of discrepancies to be expected in experimental work of this kind it is interesting that there is a remarkable similarity in the vitamin A potency of the butterfat from cows fed similar quantities of vitamin A potency, at corresponding periods of feeding, toward the end of the experiment.

Relation of Quantities of Vitamin A Potency in the Feed to Quantities in the Butterfat

The quantities of feed consumed and of milk and fat produced are given in Table 7. The calculated Sherman-Munsell units of vitamin A

TABLE 7. Consumption of feed and production of milk and butterfat, average per day

Periods	Dates of Periods	Total grain pounds	Yellow corn pounds	Alfalfa meal pounds	Milk pounds	Fat per cent	Fat pounds
Cow No. 192—Fed on Yellow Corn.							
First—	Sept. 1-7, 1934, incl.	10.00	6.00	0	27.80	2.45	.68
Second—	Sept. 8-Oct. 5, 1934, incl.	8.93	5.36	0	25.29	3.25	.82
Third—	Oct. 6-Nov. 2, 1934, incl.	8.93	5.36	0	19.35	3.7	.72
Fourth—	Nov. 3-30, 1934, incl.	8.00	4.80	0	16.00	3.55	.57
Fifth—	Dec. 1-28, 1934, incl.	8.00	4.80	0	14.50	3.8	.55
Cow No. 356—Fed on Yellow Corn.							
First—	Aug. 13-19, 1934, incl.	10.29	6.17	0	28.54	4.2	1.20
Second—	Aug. 20-Sept. 16, 1934, incl.	12.00	7.20	0	29.83	4.8	1.43
Third—	Sept. 17-Oct. 14, 1934, incl.	11.57	6.94	0	24.30	4.4	1.07
Fourth—	Oct. 15-Nov. 11, 1934, incl.	11.21	6.73	0	19.57	6.8	1.33
Last period missed on account of cow being sick.							
Cow No. 370—Fed on Yellow Corn.							
First—	Sept. 29-Oct. 5, 1934, incl.	6.29	3.77	0	25.03	4.2	1.05
Second—	Oct. 6-Nov. 2, 1934, incl.	6.14	3.69	0	24.97	4.6	1.15
Third—	Nov. 3-30, 1934, incl.	7.00	4.20	0	21.49	4.8	1.03
Fourth—	Dec. 1-28, 1934, incl.	8.00	4.80	0	18.64	5.3	.99
Fifth—	Dec. 29, 1934—Jan. 25, 1935, incl.	7.79	4.67	0	19.03	5.1	.97
Cow No. 65—Fed on 3# Alfalfa Meal and Yellow Corn daily.							
First—	Aug. 4-10, 1934, incl.	5.93	3.56	3.00	35.51	4.0	1.42
Second—	Aug. 11-Sept. 7, 1934, incl.	10.25	6.15	3.00	34.79	3.95	1.37
Third—	Sept. 8-Oct. 5, 1934, incl.	11.00	6.60	3.00	32.15	4.05	1.30
Fourth—	Oct. 6-Nov. 2, 1934, incl.	11.00	6.60	3.00	29.40	4.35	1.28
Fifth—	Nov. 3-30, 1934, incl.	11.00	6.60	3.00	27.54	4.1	1.13
Cow No. 363—Fed on Yellow Corn and 3# Alfalfa Meal daily.							
First—	July 29-Aug. 4, 1934, incl.	8.29	4.97	3.00	25.40	4.0	1.02
Second—	Aug. 5-Sept. 1, 1934, incl.	10.07	6.04	3.00	28.44	4.4	1.25
Third—	Sept. 2-29, 1934, incl.	12.00	7.20	3.00	25.40	4.4	1.12
Fourth—	Sept. 30-Oct. 27, 1934, incl.	10.07	6.04	3.00	20.50	4.5	.92
Fifth—	Last period missed on account of cow being sick.						
Cow No. 376—Fed on Yellow Corn and 3# Alfalfa Meal daily.							
First—	Sept. 8-14, 1934, incl.	5.49	3.29	2.40	17.43	3.85	.67
Second—	Sept. 15-Oct. 12, 1934, incl.	6.30	3.78	2.66	22.24	4.4	.98
Third—	Oct. 13-Nov. 9, 1934, incl.	6.64	3.99	3.00	20.61	4.85	1.00
Fourth—	Nov. 10-Dec. 7, 1934, incl.	7.00	4.20	2.45	17.97	5.2	.93
Fifth—	Dec. 8, 1934-Jan. 4, 1935, incl.	8.00	4.80	3.00	17.84	5.1	.91
Cow No. 74—Fed on Yellow Corn and 6# Alfalfa Meal daily.							
First—	Sept. 18-24, 1934, incl.	4.03	2.41	4.03	22.13	3.6	.80
Second—	Sept. 25-Oct. 22, 1934, incl.	5.72	3.43	5.58	24.79	4.0	.99
Third—	Oct. 23-Nov. 19, 1934, incl.	7.36	4.41	6.00	23.66	4.4	1.04
Fourth—	Nov. 20-Dec. 17, 1934, incl.	7.00	4.20	5.04	21.40	4.55	.97
Fifth—	Dec. 18, 1934-Jan. 14, 1935, incl.	7.79	4.67	5.86	23.61	4.25	1.00
Cow No. 301—Fed on Yellow Corn and 6# Alfalfa meal daily.							
First—	Sept. 14-20, 1934, incl.	6.00	3.60	6.00	33.69	4.1	1.38
Second—	Sept. 21-Oct. 18, 1934, incl.	7.93	4.76	6.00	35.53	4.3	1.53
Third—	Oct. 19-Dec. 15, 1934, incl.	9.25	5.55	6.00	32.15	4.7	1.51
Fourth—	Nov. 16-Dec. 13, 1934, incl.	8.00	4.80	6.00	24.84	5.05	1.25
Fifth—	Dec. 14, 1934-Jan. 10, 1935, incl.	8.00	4.80	6.00	20.80	5.1	1.06

TABLE 7. Consumption of feed and production of milk and butterfat, average per day—Continued

Periods	Dates of Periods	Total grain pounds	Yellow corn pounds	Alfalfa meal pounds	Milk pounds	Fat per cent	Fat pounds
Cow No. 364—Fed on Yellow Corn and 6# Alfalfa Meal daily.							
First—	July 22-28, 1934, incl.	7.43	4.46	6.00	25.90	4.6	1.19
Second—	July 29-Aug. 25, 1934, incl.	11.57	6.94	6.00	28.93	4.8	1.39
Third—	Aug. 26-Sept. 22, 1934, incl.	12.00	7.20	6.00	27.40	5.0	1.37
Fourth—	Sept. 23-Oct. 20, 1934, incl.	9.71	5.83	6.00	22.39	5.85	1.31
Fifth—	Oct. 21-Nov. 17, 1934, incl.	10.00	6.00	6.00	18.66	6.5	1.21

eaten in the corn and alfalfa and secreted in the butterfat are given in Table 8. It is seen in Table 8 that during the first period of seven days and the second period of 28 days, the cows receiving vitamin A potency in yellow corn alone produced appreciably more vitamin A in the butter than was present in the feed.

TABLE 8. Vitamin A potency in Sherman-Munsell rat units eaten daily and secreted in butterfat

	Date of Period	Vitamin A eaten in corn	Vitamin A eaten in alfalfa meal	Vitamin A in butter Units per gram	Vitamin A in butter-fat Units per day
No alfalfa.					
First period, 7 days					
Cow 192	9-1-34 to 9-7-34, incl.	8,710	0	.....	.....
356	8-13-34 to 8-19-34, incl.	9,517	0	.....	.....
370	9-29-34 to 10-5-34, incl.	5,472	0	.....	.....
Average per cow		7,900	0	38	16,821
Second Period, 28 days.					
Cow 192	9-8-34 to 10-5-34, incl.	7,779	0	.....	.....
356	8-20-34 to 9-16-34, incl.	10,451	0	.....	.....
370	10-6-34 to 11-2-34, incl.	5,022	0	.....	.....
Average per cow		7,751	0	23.5	12,087
Third Period, 28 days.					
Cow 192	10-6-34 to 11-2-34, incl.	7,293	0	.....	.....
356	9-17-34 to 10-14-34, incl.	10,074	0	.....	.....
370	11-3-34 to 11-30-34, incl.	5,334	0	.....	.....
Average per cow		7,567	0	12	5,116
Fourth Period, 28 days.					
Cow 192	11-3-34 to 11-30-34, incl.	6,096	0	.....	.....
356	10-15-34 to 11-11-34, incl.	8,548	0	.....	.....
370	12-1-34 to 12-28-34, incl.	5,660	0	.....	.....
Average per cow		6,768	0	8.5	3,715
Fifth Period, 28 days.					
Cow 192	12-1-34 to 12-28-34, incl.	5,660	0	.....	.....
356	Last period missed on account of cow being sick.				
370	12-29-34 to 1-25-35, incl.	5,083	0	.....	.....
Average per cow		5,372	0	5.5	1,895
3 pounds alfalfa daily.					
First Period.					
Cow 65	8-4-34 to 8-10-34, incl.	5,491	205,511	.....	.....
363	7-29-34 to 8-4-34, incl.	7,664	205,511	.....	.....
376	9-8-34 to 9-14-34, incl.	4,774	153,549	.....	.....
Average per cow		5,976	188,190	41.5	19,519

TABLE 8. Vitamin A potency in Sherman-Munsell rat units eaten daily and secreted in butterfat—Continued

	Date of Period	Vitamin A eaten in corn	Vitamin A eaten in alfalfa meal	Vitamin A in butter Units per gram	Vitamin A in butter-fat Units per day
Second Period.					
Cow 65	8-11-34 to 9-7-34, incl.	9,486	205,511	.....	.....
363	8-5-34 to 9-1-34, incl.	9,316	205,511	.....	.....
376	9-15-34 to 10-12-34, incl.	5,488	158,117	.....	.....
Average per cow		8,097	189,713	26.5	14,425
Third Period.					
Cow 65	9-8-34 to 10-5-34, incl.	9,581	191,901	.....	.....
363	9-2-34 to 9-29-34, incl.	10,451	191,901	.....	.....
376	10-13-34 to 11-9-34, incl.	5,430	178,291	.....	.....
Average per cow		8,487	187,364	22.5	11,640
Fourth Period.					
Cow 65	10-6-34 to 11-2-34, incl.	8,982	178,291	.....	.....
363	9-30-34 to 10-27-34, incl.	8,220	178,291	.....	.....
376	11-10-34 to 12-7-34, incl.	5,334	135,542	.....	.....
Average per cow		7,512	164,041	19.5	9,230
Fifth Period.					
Cow 65	11-3-34 to 11-30-34, incl.	8,383	166,042	.....	.....
363	Last period missed on account of cow being sick.				
376	12-8-34 to 1-4-35, incl.	5,660	155,154	....	....
Average per cow		7,022	160,598	13.0	6,019
6 pounds alfalfa daily.					
First Period.					
Cow 74	9-18-34 to 9-24-34, incl.	3,498	257,748	.....	.....
301	9-14-34 to 9-20-34, incl.	5,226	383,802	.....	.....
364	7-22-34 to 7-28-34, incl.	6,878	411,022	.....	.....
Average per cow		5,201	350,857	52.5	26,758
Second Period.					
Cow 74	9-25-34 to 10-22-34, incl.	4,668	331,561	.....	.....
301	9-21-34 to 10-18-34, incl.	6,477	356,582	.....	.....
364	7-29-34 to 8-25-34, incl.	10,703	411,022	.....	.....
Average per cow		7,283	366,388	35.5	20,992
Third Period.					
Cow 74	10-23-34 to 11-19-34, incl.	6,000	332,084	.....	.....
301	10-19-34 to 11-15-34, incl.	7,551	332,084	.....	.....
364	8-26-34 to 9-22-34, incl.	10,451	383,802	.....	.....
Average per cow		8,001	349,323	25.5	15,113
Fourth Period.					
Cow 74	11-20-34 to 12-17-34, incl.	5,334	260,604	.....	.....
301	11-16-34 to 12-13-34, incl.	6,096	310,308	.....	.....
364	9-23-34 to 10-20-34, incl.	7,932	356,582	.....	.....
Average per cow		6,454	309,165	21.5	11,474
Fifth Period.					
Cow 74	12-18-34 to 1-14-35, incl.	5,083	281,748	.....	.....
301	12-14-34 to 1-10-35, incl.	5,225	288,532	.....	.....
364	10-21-34 to 11-17-34, incl.	8,166	332,084	.....	.....
Average per cow		6,158	300,788	15.0	7,420

A comparison of the average consumption of vitamin A potency in the feed and its recovery in the butterfat are given in Table 9. The apparent utilization varies from 212.9 to 2.4 per cent, depending on the quantity of vitamin A potency of the feed and the period of time after the experiment had begun—that is, the extent of depletion of the cow. The apparent percentage recovered in the fat is greatest with the cows receiving the least amount of vitamin A in the feed. This is due to the use of larger proportions of the carotene and vitamin A stored in the body by the cow receiving feed low in carotene. Similar results were secured in previous work (5).

As has already been pointed out, these figures represent only the apparent utilization of the vitamin A potency, and not its actual utilization, since some of the vitamin A in the butter came from that stored in the body of the cow. The relative quantity of the stored vitamin A potency which was secreted in the butter is greatest when the least amount of vitamin A potency is present in the feed. For this reason the apparent utilization is highest when the least vitamin A potency is fed. It is of course possible that the cow may utilize small quantities of vitamin A better than large quantities, and the results presented in the bulletin seem to indicate that this is probable.

TABLE 9. Vitamin A potency in feed, and in butter, and apparent percentage recovered

	Period	Vitamin A total corn and alfalfa average per day per cow	Total Vitamin A in butter-fat average per day per cow	Recovered average per cent
Series 0.				
No alfalfa	1	7,900	16,821	212.9
	2	7,751	12,087	155.9
	3	7,567	5,116	67.6
	4	6,768	3,715	54.9
	5	5,372	1,895	35.3
Series 3.				
3 pounds of alfalfa	1	194,166	19,519	10.1
	2	197,810	14,425	7.3
	3	195,851	11,640	5.9
	4	171,553	9,230	5.4
	5	167,620	6,019	3.6
Series 6.				
6 pounds of alfalfa	1	356,058	26,758	7.5
	2	373,671	20,992	5.6
	3	357,324	15,113	4.2
	4	315,619	11,474	3.6
	5	306,946	7,420	2.4

Units of Vitamin A Required in the Feed over Maintenance Requirements for a Unit of Vitamin A in the Butter

The fact that a reserve of vitamin A is stored in the body of the animal makes the estimation of the utilization of vitamin A by the animal somewhat complicated. When two groups of animals are fed at two levels of vitamin A, the vitamin A in the butter produced during a definite period is due to the effects of that in the feed plus that in the bodies. If it is assumed that the vitamin A stored in the bodies of the cows is the same in both groups, then the difference in the quantity of vitamin A in the butters is due to the difference in vitamin A in the feed.

Subtracting one from the other cancels out the effects of vitamin A stored, if the stores are assumed to be the same. This assumption is better justified if a large number of animals is used, than if the number is small, since the stores in individual animals vary, while in large groups these individual differences are averaged out.

In previous work it was calculated, by the procedure mentioned above but at lower levels of feeding, that 6 to 13 units of vitamin A are required in the feed for one unit in the butterfat. Only one cow was used in each group; for this reason the results are uncertain. The levels fed were about 8,400, 60,000, and 116,000 Sherman-Munsell rat units per day.

In the work here reported, three cows were used in each group, and approximately 7,000, 170,000, and 340,000 Sherman-Munsell rat units were fed per day.

The results of the calculations for each individual period and the totals of the five periods are given in Table 10. While there are some

TABLE 10. Utilization of vitamin A potency for butterfat Sherman-Munsell units per cow per day

	Period 1	Period 2	Period 3	Period 4	Period 5	Total for 5 periods
In butter, series 3....	19,519	14,425	11,640	9,230	6,019	60,833
In butter, series 0....	16,821	12,087	5,116	3,715	1,895	39,634
In butter, gain over 0	2,698	2,338	6,524	5,515	4,124	21,199
In feed, series 3......	194,166	197,810	195,851	171,553	167,620	927,000
In feed, series 0......	7,900	7,751	7,567	6,768	5,372	35,358
In feed, gain over 0..	186,266	190,059	188,284	164,785	162,248	891,642
Per cent utilized.....	1.45	1.23	3.46	3.35	2.54	2.38
In butter, series 6....	26,758	20,992	15,113	11,474	7,420	81,757
In butter, series 3....	19,519	14,425	11,640	9,230	6,019	60,833
In butter, gain over 3	7,239	6,567	3,473	2,244	1,401	20,924
In feed, series 6......	356,058	373,671	357,324	315,619	306,946	1,709,618
In feed, series 3......	194,166	197,810	195,851	171,553	167,620	927,000
In feed, gain over 3..	161,892	175,861	161,473	144,066	139,326	782,618
Per cent utilized...	4.47	3.73	2.15	1.56	1.01	2.67
In butter, series 6....	26,758	20,992	15,113	11,474	7,420	81,757
In butter, series 0....	16,821	12,087	5,116	3,715	1,895	39,634
In butter, gain over 0	9,937	8,905	9,997	7,759	5,525	42,123
In feed, series 6......	356,058	373,671	357,324	315,619	306,946	1,709,618
In feed, series 0......	7,900	7,751	7,567	6,768	5,372	35,358
In feed, gain over 0..	348,158	365,920	349,757	308,851	301,574	1,674,260
Per cent utilized...	2.85	2.43	2.86	2.51	1.83	2.52

differences between these various periods, the results on the whole are quite uniform. On an average, 2.5% of the vitamin A potency of the feed was found in the butter after allowance was made for vitamin A stored in the body of the cows, on the assumption that the quantity stored in each group of 3 cows was equal.

It is evident from these results that the cow is not very efficient in utilizing carotene of the feed for the production of vitamin A potency in the milk. Only 2.5% of the vitamin A potency was recovered in the butter. In similar experiments with chickens, we found that four units of vitamin A in the feed produced one unit in the egg. The chicken therefore utilizes 25% of the vitamin A fed, which is practically 10 times as much as that utilized by the cow.

While these cows utilized only about 2.5% of the vitamin A potency at the high levels fed, it still remains possible that at lower levels the cow utilizes the carotene more efficiently, so that the results previously reported (5) are approximately correct, and that the cow may utilize 10 per cent of the carotene at such levels. This matter requires further study with a larger number of cows than were used in the previous work.

Individual Variations in the Vitamin A Potency of Butterfat

The vitamin A potency of the butterfat discussed in the preceding pages was estimated in mixtures of the samples (usually 3) from the cows on the same feed for the same period, and not in the individual samples of butterfat, because the number of rats available did not permit testing the large number of samples. Carotene and spectro-vitamin A were estimated in all but one of the individual samples. Sample 40631 was used up before the spectro-vitamin A was run. Carotene was estimated by the spectroscopic method previously described (15). Spectro-vitamin A was estimated on the unsaponifiable residue of the butterfat by methods which will be described in full. The spectro-vitamin A was calculated by the same method employed by Baumann and Steenbock (1), and Gillam et al (8,9), and is reported as vitamin A, as was done by them. The calculation is based upon the assumption that the value of E, or density of vitamin A in a 1 per cent solution at 1 cm, is 1600. If 1600 E at 1% and 1 cm equals one million parts per million vitamin A, then one E is equal to 625 parts per million of vitamin A or 3.13 parts per million if E is 100 per cent and 2 cm. We term the results spectro-vitamin A for convenience. Other workers (10) have multiplied E by 1600 to convert the reading to international units per gram, but this factor is not correct for the results we have secured with butterfat, as will appear later.

The carotene and the spectro-vitamin A in parts per million for each individual sample of butterfat are given in Table 11. The calculated vitamin A potencies in Sherman-Munsell rat units are also given. These were calculated by the following procedure: The carotene and spectro-vitamin A were averaged for each group of samples on which the vitamin potency had been determined. The average carotene was multiplied by 1.4 to convert it to Sherman-Munsell rat units. This is the factor secured in this laboratory both for carotene dissolved in cottonseed oil and for the international standard (7). The average carotene

TABLE 11. Vitamin A potency of butter in Sherman-Munsell units calculated from analysis

Laboratory Number	Weeks on experiment	Cow No.	Carotene parts per million	Vitamin A spectro parts per million	Vit. A potency Sherman-Munsell units per gram	Units for one part per million of spectro Vit. A	Calculated Vit. A potency in rat units	International units per gram (rat units x 1.2)
No alfalfa.								
40592	0	356	29.50	.....	.....	.....	62	74
40631	0	192	7.98	sample	exhausted	.....	.....	.....
40899	0	370	12.59	8.6	.....	.....	36	43
40930 Average	....	....	16.69	9.1	43	2.16	.....	.....
40595	1	356	11.29	2.8	.....	.....	33	40
40638	1	192	5.52	3.9	.....	.....	32	39
40923	1	370	6.81	3.7	.....	.....	33	39
40961 Average	....	....	7.87	3.5	33	6.28	.....	.....
40870	5	356	3.25	3.0	.....	.....	17	21
40922	5	192	1.65	2.9	.....	.....	15	18
41065	5	370	1.22	1.8	.....	.....	9	11
41131 Average	....	....	2.04	2.6	14	4.28	.....	.....
41063	9	192	.52	1.8	.....	.....	7	8
40927	9	356	1.74	3.2	.....	.....	13	16
41256 Average	....	....	1.13	2.5	10	3.37	.....	.....
41102	13	356	1.48	1.6	.....	.....	8	9
41215	13	192	.33	1.8	.....	.....	7	8
41264	13	370	.47	1.7	.....	.....	7	8
41299 Average	....	....	.76	1.7	7	3.49	.....	.....
41263	17	192	.46	1.8	.....	.....	5	6
41354	17	370	.26	1.2	.....	.....	3	4
41384 Average	....	....	.36	1.5	4	2.33	.....	.....
3 pounds alfalfa								
40579	0	65	13.35	3.7	.....	.....	38	45
40582	0	363	8.90	6.8	.....	.....	47	57
40639	0	376	6.87	10.7	.....	.....	65	77
40921 Average	....	....	9.71	7.1	50	5.13	.....	.....
40581	1	363	9.37	3.5	.....	.....	39	47
40593	1	65	13.37	2.5	.....	.....	37	45
40656	1	376	8.65	5.3	.....	.....	52	62
40951 Average	....	....	10.46	3.8	33	7.46	.....	.....
40630	5	363	4.69	3.2	.....	.....	19	23
40637	5	65	8.82	2.5	.....	.....	22	27
40928	5	376	3.13	3.5	.....	.....	18	22
41134 Average	....	....	5.55	3.1	20	3.95	.....	.....
40898	9	363	3.45	3.4	.....	.....	25	31
40921	9	65	6.72	3.0	.....	.....	28	33
41103	9	376	2.00	3.2	.....	.....	22	27
41231 Average	....	....	4.06	3.2	25	6.07	.....	.....
41060	13	363	1.73	2.9	.....	.....	13	15
41064	13	65	7.87	1.4	.....	.....	16	19
41220	13	376	.77	3.5	.....	.....	13	16
41265 Average	....	....	3.46	2.6	14	3.52	.....	.....
41214	17	65	5.60	2.0	.....	.....	13	15
41308	17	376	2.23	3.3	.....	.....	11	13
41312 Average	....	....	3.92	2.7	12	2.41	.....	.....
6 pounds alfalfa								
40574	0	364	10.58	6.3	.....	.....	58	70
40655	0	301	8.88	6.9	.....	.....	60	72
40867	0	74	10.00	7.8	.....	.....	68	81

TABLE 11. Vitamin A potency of butter in Sherman-Munsell units calculated from analysis—Continued

Laboratory Number	Weeks on experiment	Cow No.	Carotene parts per million	Vitamin A spectro parts per million	Vit. A potency Sherman-Munsell units per gram	Units for one part per million of spectro Vit. A	Calculated Vit. A potency in rat units	International units per gram (rat units x 1.2)
40952 Average	....	....	9.82	7.0	62	6.89	.....	.....
40580	1	364	6.26	3.1	.....	.....	31	37
40868	1	74	13.11	4.8	.....	.....	52	63
40869	1	301	9.13	4.8	.....	.....	47	56
40955 Average	....	....	9.50	4.2	43	7.07	.....	.....
40610	5	364	5.00	3.1	.....	.....	28	33
40962	5	74	4.78	2.9	.....	.....	26	31
40963	5	301	5.44	3.2	.....	.....	29	35
41132 Average	....	....	5.07	3.1	28	6.74	.....	.....
40871	9	364	4.36	2.3	.....	.....	18	21
41136	9	74	3.91	3.3	.....	.....	22	26
41137	9	301	5.32	4.2	.....	.....	29	34
41218 Average	....	....	4.53	3.3	23	5.05	.....	.....
40964	13	364	6.32	2.0	.....	.....	18	21
41221	13	301	4.49	3.5	.....	.....	22	27
41257	13	74	4.01	3.2	.....	.....	20	24
41282 Average	....	....	4.94	2.9	20	4.51	.....	.....
41138	17	364	1.74	2.2	.....	.....	6	7
41307	17	301	5.94	3.6	.....	.....	14	17
41343	17	74	3.06	3.4	.....	.....	10	12
41385	....	....	3.58	3.1	10	1.61	.....	.....

(in rat units) was subtracted from the average vitamin A potency as directly determined on the mixture. The difference is the vitamin A potency due to the spectro-vitamin A. This difference was therefore divided by the average spectro-vitamin A in the sample to get a factor to convert spectro-vitamin A to rat units. A different factor was thus secured for each mixture. The spectro-vitamin A in the corresponding individual samples was multiplied by the corresponding factor, and the result was considered to be the vitamin A potency due to the spectro-vitamin A. The carotene in each sample was multiplied by 1.4, and the vitamin A potency so secured was added to that calculated from the spectro-vitamin A, and the total was the calculated Sherman-Munsell units of vitamin A potency. These are given in Table 11 for each sample.

The carotene content of the individual butterfat secured 5 days after calving varied from 6.87 to 29.50 parts per million. Excluding the butter containing 29.5 parts per million, which was extremely high in carotene, the variation was from 6.87 to 13.35 parts per million. Cow 356, which gave the butterfat containing 29.50 parts per million of carotene in the first period, continued to give butterfat containing considerably more carotene than the other two cows during the other periods. No butterfat was secured from this cow during the last period. The vitamin A potency of the butterfat of this cow was also the highest of the three in the same group for all the periods in which it was collected.

The vitamin A potency of the butterfat of cow 370 was less than that of the other two cows in the periods for which it was collected. In three of the periods the differences were large; in the others they were small. The carotene in the butter from cow 370 was also usually lower than that of the others in the group.

Both the carotene content and the vitamin A potency of the butterfat of cow 356 was higher during all periods than those of the other two cows in the same group. The vitamin A potency of the butterfat of cow 65 was higher than that of the other two cows in the same group for the last four samples, but slightly lower in the first two samples. The carotene content of the butterfat of this cow No. 65 was apparently higher than that of the other two in all samples. The vitamin A potency of the butterfat of cow 301 was higher than that of the other two cows in the same group in all except the first two periods, though the carotene was in some cases higher and in other cases lower than that of the other two.

It appears, therefore, that some cows may have a greater power than others to secrete vitamin A and carotene into the butter.

Rate of Utilization of Vitamin A Potency (Carotene)

Work reported in Texas Bulletin 495 (5) shows that although the vitamin A content of butter decreased during the lactation period of the cow, this decrease was not due to the inability of the cow to utilize vitamin A, because when cows previously producing butter containing only one or five units of vitamin A were placed on pasture, the vitamin A potency of the butter increased to 25 or 35 units per gram within two weeks.

In order to estimate how rapidly the cow transferred the carotene from the feed to the butterfat, several lots of cows were first depleted of vitamin A by being fed feed low in this vitamin for several months. They were then placed upon the feed to be tested and samples of butter were taken at regular intervals.

In the first experiment of this kind, after a depletion period of 60 days, the cows were placed upon pasture for five hours a day. The results are given in Table 13. It is seen that the vitamin A potency of the butter increased from 12 units per gram to 40 or 50 units per gram within three days. A maximum was thus attained in three days after the cows were put on pasture. After this time, there was some decrease. As shown in Texas Bulletin 513 (15), the carotene content of this butter continued to increase after the vitamin A potency had apparently reached the maximum.

In a second experiment, the depleted cows were placed on sorghum silage, preserved by means of acid. This product is termed A. I. V. silage and is a patented process of A. I. Vertanen. Grass and alfalfa

TABLE 12. **Butter from cows on pasture and from goats**

Laboratory Number	Date of Samples	Days on grass pasture	Days after lactation begun	Carotene in butterfat parts per million	Vitamin A potency—butterfat Sherman-Munsell units per gram	International units per gram (rat units x 1.2)
	Cow 301, depleted and placed on grass pasture.					
39124	Nov. 20, 1933............	0	70	0.53	12	14
39127	Nov. 22, "	1	72	0.78	20	24
39128	Nov. 23, "	2	73	3.03	30	36
39131	Nov. 24, "	3	74	3.73	50	60
39132	Nov. 25, "	4	75	4.79	40	48
39134	Nov. 28, "	7	78	6.13	33	40
39138	Dec. 5, "	14	85	8.03	40	48
	Cow 311, depleted and placed on grass.					
39125	Nov. 20, 1933............	0	70	0.44	12	14
39126	Nov. 22, "	1	72	0.84	18	22
39129	Nov. 23, "	2	73	2.43	40	48
39130	Nov. 24, "	3	74	4.43	40	49
39133	Nov. 25, "	4	75	6.09	40	48
39135	Nov. 28, "	7	78	7.45	25	30
39139	Dec. 5, "	14	85	9.94	40	48
	Goats on pasture.					
37741	June 15, 1933............	..	Late stage	0.40	40	48
39740	May 8, 1934............	..	45-60	0.47	50	60

preserved by this process retain high quantities of carotene (12). The procedure we used was the same as that followed by Peterson et al (12) and described in full by them. The quantity of a 2 N mixture of 4 molecules of hydrochloric acid and 1 molecule of sulphuric acid required to make the sorghum have a pH 3.45 with 10% excess, was ascertained by preliminary tests. This quantity of acid was sprinkled on the material while it was being put into the silo. This was done about October 20, 1934. The cows were depleted and then given the A. I. V. sorghum silage. The cows did not eat the A. I. V. sorghum silage well. The amount of carotene in this silage was 1.4 parts per million. This silage did not seem to contain any more carotene than ordinary sorghum silage and its vitamin A potency was so low that it had little effect upon the butter of the cows. The results are given in Table 13.

According to this experiment, the A. I. V. process did not seem to be at all suitable for the preparation of sorghum silage and sorghum silage produced by it was not sufficiently high in carotene to justify the use of the process, as it is expensive.

After it was evident that the special A. I. V. sorghum silage was ineffective in raising the butterfat in vitamin A, the same cows were placed upon pasture. The result was an immediate and rapid increase in vitamin A potency of butter. The carotene in the butterfat reached a maximum of 13.96 parts per million with cow No. 322 after 28 days, and a maximum of 19.06 with cow No. 311 in 14 days, followed by a decrease with both cows. This may have been due to a decrease in the quality of the pasture.

TABLE 13. Effect of silage and pasture upon vitamin A potency of butterfat

Laboratory Number	Feed	Days on silage or grass	Spectro Vitamin A parts per million	Carotene parts per million	Calculated Vitamin A potency Sherman-Munsell units per gram	International units per gram (rat units x 1.2)
	Cow No. 311.					
41970	AIV sorghum silage........	0	1.9	.57	8	10
41972	"	2	1.6	.67	6	8
41974	"	3	1.9	.60	8	10
41976	"	4	2.6	.64	13	16
41978	"	5	2.8	.63	14	17
42272	"	9	2.5	1.10	13	16
42273	"	17	2.2	1.26	11	14
42312	On pasture July 9.........	2	7.5	2.87	50	60
42313	"	3	7.7	4.02	53	63
42314	"	4	9.1	6.03	65	78
42315	"	5	9.3	6.98	68	81
42766	"	14	11.8	19.06	101	122
42767	"	28	9.0	18.06	81	97
42769	"	44	10.2	17.06	88	105
42768	"	58	7.9	15.21	70	84
	Cow No. 322.					
41971	AIV sorghum silage.......	0	1.8	.61	8	9
41973	"	2	1.6	.59	6	7
41975	"	3	2.6	1.13	14	17
41977	"	4	2.8	.69	15	17
41979	"	5	2.4	1.25	13	15
42274	"	9	2.0	1.40	10	12
42275	"	17	2.8	1.49	16	19
42316	On pasture, July 9, 1935..	2	5.7	2.15	36	44
42317	" ..	3	5.0	2.68	32	39
42318	" ..	4	4.2	3.99	29	34
42319	" ..	5	4.7	5.01	34	40
42770	" ..	14	9.2	10.47	72	86
42771	" ..	28	6.2	13.96	56	67
42772	" ..	44	6.0	12.56	53	64
42773	" ..	58	6.5	10.87	54	65

The spectro-vitamin A reached a maximum in 14 days with both cows, after which there was some decrease. There was a very rapid increase in the spectro-vitamin A. Within 2 days it had doubled with cow No. 322 and more than trebled with cow No. 311. Cow No. 311 apparently had a greater capacity to secrete vitamin A and carotene in the butterfat than cow No. 322.

The vitamin A potency in these samples was not determined by means of rats, but was calculated from the analysis. The method of calculation used was as follows: The carotene in parts per million was multiplied by 1.4 and the product was assumed to be Sherman-Munsell rat units of vitamin A potency per gm (7). The spectro-vitamin A in parts per million was corrected for pseudo-spectro vitamin A by subtracting 0.8, and the remainder was multiplied by 6.8 to convert the result to Sherman-Munsell units per gm (6). The sum of the vitamin A potency derived from carotene and that derived from spectro-vitamin A is the total given in Table 13.

The A. I. V. sorghum silage increases the vitamin A potency of the butterfat to some extent, but not to a great extent. On the other hand, the calculated vitamin A potency is increased rapidly and greatly by the pasture. The maximum was reached in 14 days by both cows, after which there was a decrease. The butterfat of cow No. 311 was higher in vitamin A potency than that of cow No. 322.

The calculated vitamin A potency of the butter of these two cows was quite high when the cows had access to good pasture, reaching a maximum of 72 Sherman-Munsell units with cow No. 322 and 101 units with cow No. 311. The question arises whether these calculated values are too high for the butterfat in question, as they are much higher than those given in Table 5.

Similar calculations were made for analyses given by Peterson, Bohstedt, Bird, and Beeson in their Table 6 (12), with the results given in Table 14. The vitamin A potency of the butterfat of the cows on pasture was quite high, and similar to the results secured by us. The butterfat

TABLE 14. Calculated vitamin A potency of butterfat—Peterson et al.

	Carotene parts per million	Spectro Vitamin A parts per million	Vitamin A potency Sherman Munsell units	International units per gram
Winter ration 180 days.				
Guernsey	6.0	2.9	23	28
Holstein	3.5	4.0	27	32
Jersey	3.7	3.1	21	25
Brown Swiss	3.4	5.8	29	35
Average (calculated)	4.2	4.0	28	34
A I V Alfalfa silage 49 days.				
Guernsey	9.5	8.5	66	79
Holstein	5.4	10.0	70	84
Jersey	7.1	7.7	57	68
Brown Swiss	5.0	9.7	68	82
Average	6.8	9.0	65	78
Pasture, 20 days.				
Guernsey	17.0	8.7	78	94
Holstein	6.6	15.0	106	127
Jersey	10.7	10.2	79	95
Brown Swiss	9.8	12.6	94	113
Average	11.0	11.6	89	107

from the cows on the winter ration was also comparatively high in vitamin A potency, but these cows were receiving a ration quite high in carotene.

Calculations were also made from some of the analyses of Gillam and Heilbron (9) as shown in Table 15. These cows received A. I. V. silage made from grass, and one lot received dried grass in addition. The vitamin A potency of this English butter, even with the highest amount of dried grass, is appreciably lower than that in the Wisconsin samples from the cows on A. I. V. alfalfa silage, as shown in Table 14.

The cows on the Wisconsin winter ration were receiving approximately 298 to 357 milligrams of carotene per day, and those on their A. I. V.

TABLE 15. Calculated vitamin A potency of butterfat (Gillam and Heilbron) groups of 2 Devon cows

Group	Ration	Date of milk sample	Carotene per million	Spectro Vitamin A per million	Total potency Sherman-Munsell units
D1	Control	1-16-33	.40	2.92	15
		2-16-33	1.46	2.98	17
		2-27-33	1.64	2.86	16
		3-20-33	.25	2.68	13
D2	40 lb. A. I. V. fodder per cow per day	1-17-33	6.07	6.30	46
		2- 7-33	1.88	5.19	32
		2-28-33	3.47	4.94	33
		3-21-33	1.64	4.07	25
		4- 2-33	1.70	7.15	46
D3	70 lb. A. I. V. fodder per cow per day	1-18-33	5.43	3.72	27
		2- 8-33	4.48	4.28	30
		3- 1-33	3.25	4.82	32
		4-12-33	1.52	6.93	44
D4	70 lb. A. I. V. fodder + 4 lb. dried grass per cow per day	1-18-33	6.38	5.70	42
		2- 9-33	3.62	5.75	39
		3- 2-33	3.86	4.42	30
		3-22-33	3.88	5.92	40

silage received from 510 to 561 mg. per day. This is equivalent to about 417,000 to 500,000 and 714,000 to 785,000 Sherman-Munsell units per day and about 506,000 to 607,000 and 867,000 to 953,000 international units per day.

It is interesting to compare the vitamin A potency of butterfat secured in the work here and previously reported with the values calculated from the work of Peterson et al (12) and Baumann et al (1). These are given in Table 16. Although there are some variations, the vitamin A

TABLE 16. Approximate relation between vitamin A potency in feed and vitamin A in butterfat after about 9 weeks (Sherman-Munsell units)

Units per day	Units per gram of butter	Reference
0	8	This bulletin
7,000	10	"
8,400	8	"
17,000	7	"
60,000	14	"
116,000	12	"
170,000	25	"
340,000	23	"
450,000	28	12
350,000	45	2
750,000	65	12
1,400,000	95	2

potency of the butter is related to the potency fed daily. According to these calculations, from 750,000 to 1,400,000 Sherman-Munsell units are required to produce butterfat containing from 65 to 95 Sherman-Munsell units per gram.

SUMMARY

Three groups of three Jersey cows each received feed having a vitamin A potency averaging 7,000, 170,000, and 340,000 Sherman-Munsell units per day. The vitamin A potency was furnished by yellow corn and heat-dried alfalfa meal. Samples of butter were collected over a period of seventeen weeks. The vitamin A potency of the butter and of the feed was determined in Sherman-Munsell units by means of rats, the butter for the three cows on the same level for the same period of time being mixed together for this purpose. Carotene and spectro-vitamin A were determined in the individual samples of butter.

The vitamin A potency of the butter decreased from 43 to 62 Sherman-Munsell units at the beginning of the experiment to 4, 12, and 10 units at the end of seventeen weeks. The carotene decreased from 9.7 to 16.7 parts per million carotene in the beginning to 0.4, 3.9, and 3.6 at the end of seventeen weeks.

The apparent utilization of the vitamin A potency varied from 213 to 2.4%. The apparent percentage recovered was greatest at the beginning of the experiment and for the cows receiving the least amount of vitamin A in the feed. This was due to the use of larger proportions of the carotene and vitamin A stored in the body of the cow by the cow receiving feed low in carotene.

If correction is made for the vitamin A potency stored by the cows, the utilization was 2.38 to 2.67% for an average for the five periods.

The vitamin A potency in the individual samples of butterfat was calculated from the carotene content and the spectro-vitamin A. The vitamin A potency of the butterfat from some of the cows was higher than that of others on the same feed for the same period of time. Some cows appear to have a greater power than others to secrete vitamin A and carotene into the butter.

When two cows were depleted by feed low in vitamin A and then placed upon pasture, the vitamin A potency of the butter increased from 12 units per gram to 40 or 50 units per gram within three days.

A. I. V. sorghum silage was low in carotene and had only a slight effect upon the carotene and vitamin A in the butter when fed to cows previously depleted.

When these depleted cows were placed upon pasture, there was a rapid and immediate increase in the vitamin A potency of the butter. The carotene in the butterfat reached the maximum of 13.96 parts per million with cow No. 322 in 28 days and a maximum of 19.06 with cow No. 311 in 14 days, followed by a decrease with both cows. There was a rapid increase in spectro-vitamin A, which reached a maximum in 14 days. One cow apparently had a greater capacity to secrete vitamin A and carotene in the butterfat than the other.

The calculated vitamin A potency of the butter of the cows on pasture was high, having a maximum of 72 Sherman-Munsell units with one cow and 101 units for the other as calculated from the carotene and spectro-vitamin A. Results reported by Peterson and associates gave a calculated value of 79 to 106 Sherman-Munsell units per gram for cows on pasture twenty days. Cows of Gillam and Heilbron gave butterfat having a calculated vitamin A potency of only about 40 units per gram, although fed liberal amounts of A. I. V. grass fodder and dried grass.

From consideration of the available results, it is seen that the vitamin A potency of the butter is closely related to the vitamin A potency of the feed and the period of time the cow has been receiving it. From 750,000 to 1,400,000 Sherman-Munsell units are required per cow per day to produce butterfat containing from 65 to 95 Sherman-Munsell units per gram.

The number of units required to maintain a cow in good health with a good production of butterfat does not appear from the results heretofore published but it is under investigation by us.

REFERENCES

1. Baumann, C. A., and Steenbock, H., 1933. Fat-soluble vitamins. XXXVI. The carotene and vitamin A content of butter. Jour. Biol. Chem., 101:547.

2. Baumann, C. A., Steenbock, H., Beeson, W. M., and Rupel, I. W., 1934. Fat-soluble vitamins. XXXIX. The influence of breed and diet of cows on the carotene and vitamin A content of butter. Jour. Biol. Chem., 105:167.

3. Copeland, O. C., and Fraps, G. S., 1933. Sorghum silage as a source of vitamin A for dairy cows. Tex. Agr. Exp. Sta. Bull. 473.

4. Fraps, G. S., and Treichler, R., 1932. Quantitative variations in vitamin A content of butter fat. Ind. & Eng. Chem., 24:1079.

5. Fraps, G. S., Copeland, O. C., and Treichler, R., 1934. The vitamin A requirements of dairy cows. Tex. Agr. Exp. Sta. Bull. 495.

6. Fraps, G. S., and Kemmerer, A. R., 1936. Spectrographic estimation of vitamin A in butter (not yet published).

7. Fraps, G. S., Treichler, R., and Kemmerer, A. R., 1936. Relation of the carotene content to the vitamin A potency of feeds. Jour. of Agri. Research, 53:713-716.

8. Gillam, A. E., Heilbron, I. M., Morton, R. A., Bishop, G., and Drummond, J. C. 1933. CXIV. Variations in the quality of butter, particularly in relation to the vitamin A, carotene and xanthophyll content as influenced by feeding artificially dried grass to stall-fed cattle. Biochem. Jour. 28:878-888.

9. Gillam, A. E., and Heilbron, I. M. 1934. The carotenoid and vitamin A content of the butter. Biochem. Jour., 28:1082.

10. Levy, M. 1936. Second conference on vitamin standardization. Committee report. Quart. Bull. Health Org. League of Nations, 3:428-40. 1934. (Chemical Abstracts, 30:5627).

11. Meigs, E. B. 1935. Vitamin A activity indicated by yellow color of milk fat. Milk Plant Monthly, 24, No. 8:38. (Chemical Abstracts, 29:6963).

12. Peterson, W. H., Bohstedt, G., Bird, H. R., and Beeson, W. M. 1935. The preparation and nutritive value of A. I. V. silage for dairy cows. Jour. of Dairy Science, 18:63.

13. Russell, W. C., Taylor, M. W., Chichester, D. F., and Wilson, L. T. 1935. Relation between the vitamin A content of the dairy ration and that of milk. N. J. Agri. Expt. Sta. Bull., 592:3-11.

14. Sherwood, R. M., and Fraps, G. S. 1934. The amount of vitamin A potency required by hens for egg production. Tex. Agr. Expt. Sta. Bull., 493.

15. Treichler, R., Grimes, M. A., and Fraps, G. S. 1935. Relation of the color and carotene content of butter fat to its vitamin A potency. Tex. Agr. Expt. Sta. Bull., 513.